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An Assessment of Goodrich Ice Detector Performance In Various Icing Conditions

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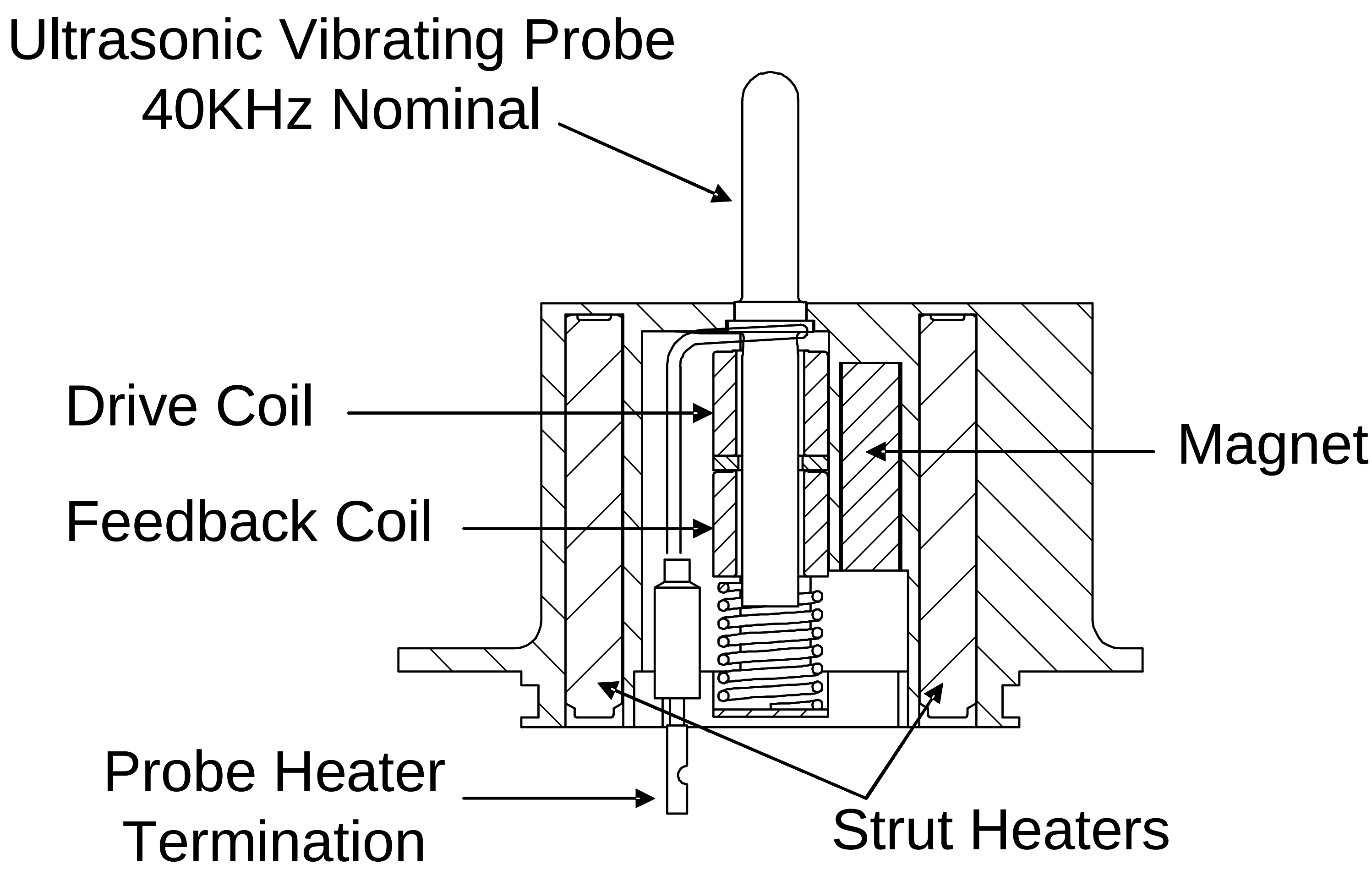
Outline

- Ice Detector Description
  - How does it work?
- Ice Accretion/Detection Physics
  - Minimum Ice Accretion Rates
  - Maximum Ice Accretion Rates
  - Ice Detector Sensitivity and Responsiveness
- Experimental Data
  - Ice Detector Repeatability
  - Low LWC Threshold
  - Large Droplet Effects
- Summary and Conclusions

Ice Detection Principles

- The Goodrich Ice Detector probe and electronics are tuned to resonate at approximately 40 KHz.
- The probe is made of a magnetic material and is forced to resonate at its natural frequency by magnetostriction.
- Magnetostriction is the ability of certain materials to expand or contract in the presence of a magnetic field.
- As ice accretes on the probe, the resonant frequency reduces due to the added ice *mass*.
- Reduction of the probe frequency below a predetermined threshold causes the ICE signal to be activated and the strut and probe to be deiced.

Cut-Away of Strut



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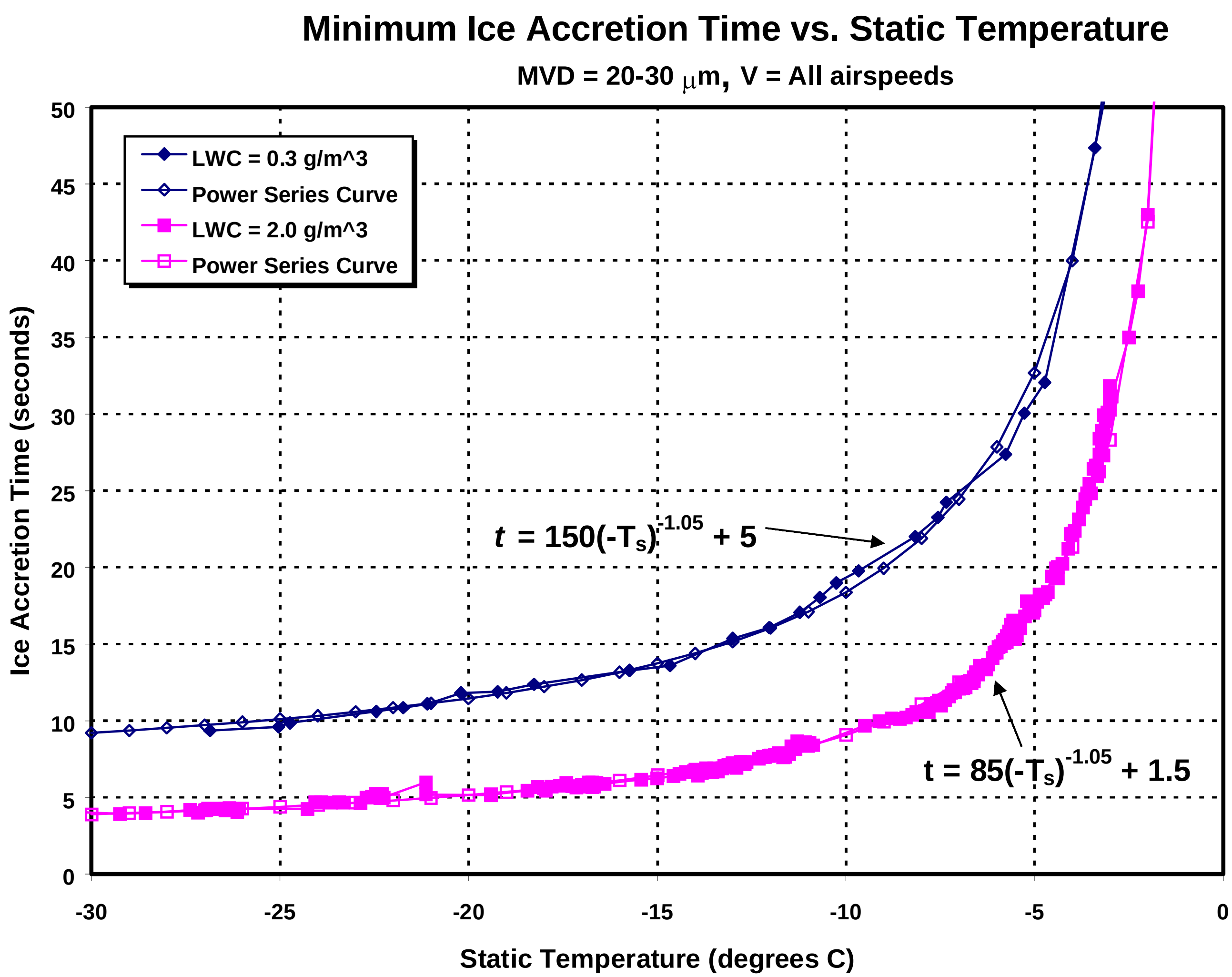
Ice Accretion / Detection Physics

- Ice accretion (response) time is inversely proportional to the ice accretion rate.

$$t \propto -\Delta f / W \quad \text{or} \quad t \propto -\Delta f / EmVn$$

- Minimum ice accretion rate yields maximum accretion time
  - The practical limitation for in-flight ice accretion is when the freezing fraction, $n \to 0$
  - The maximum ice accretion time is therefore infinity, ∞
- Maximum ice accretion rate yields minimum accretion time
  - The practical limitation is that supercooled liquid water does not exist below certain temperatures (~ -40 °C)
  - The maximum ice accretion rate for a given temperature occurs when $n = 1$
  - Other conditions at the same temperature can also produce the maximum ice accretion rate for $n < 1$
  - The minimum ice accretion time is a function of several variables

Minimum Ice Accretion Times



Sensitivity / Responsiveness

- Ice Accretion Capability/Sensitivity
  - Laws of Classical Mechanics require that an infinitesimal change in the probe mass will cause an infinitesimal change in the probe frequency
- Sensitivity (What's your reference point?)
  - At ice detector versus at other aircraft structures (wing, wiper nut, etc.)
  - Dependent on installation effects (LWC concentration, etc.)
- Responsiveness (How long does it take to detect?)
  - Ice accretion rate dependent
    - Slow ice accretion rates give pilots more time to identify conditions prior to detection by ice detector, while fast ice accretion rates may be detected prior to pilot recognition of ice accretion.
  - Dependent on ice detector trip threshold
    - Most ice detectors have a detection threshold of approx. 0.020"

Sensitivity / Responsiveness

- Since the ice detection frequency threshold is a constant…

$$-\Delta f \cdot k_1 = t \cdot W_{ID} = k_2 (t \cdot W_{wing}) = constant$$

- Where W = ice accretion rate, $W \propto EmVn$

  Δf = ice detection frequency shift threshold (constant)

  t = ice detector accretion (response) time

  k_1 = probe sensitivity constant

  $$k_2 \propto \frac{(EmVn)_{ID}}{(EmVn)_{Wing}} \cong constant$$

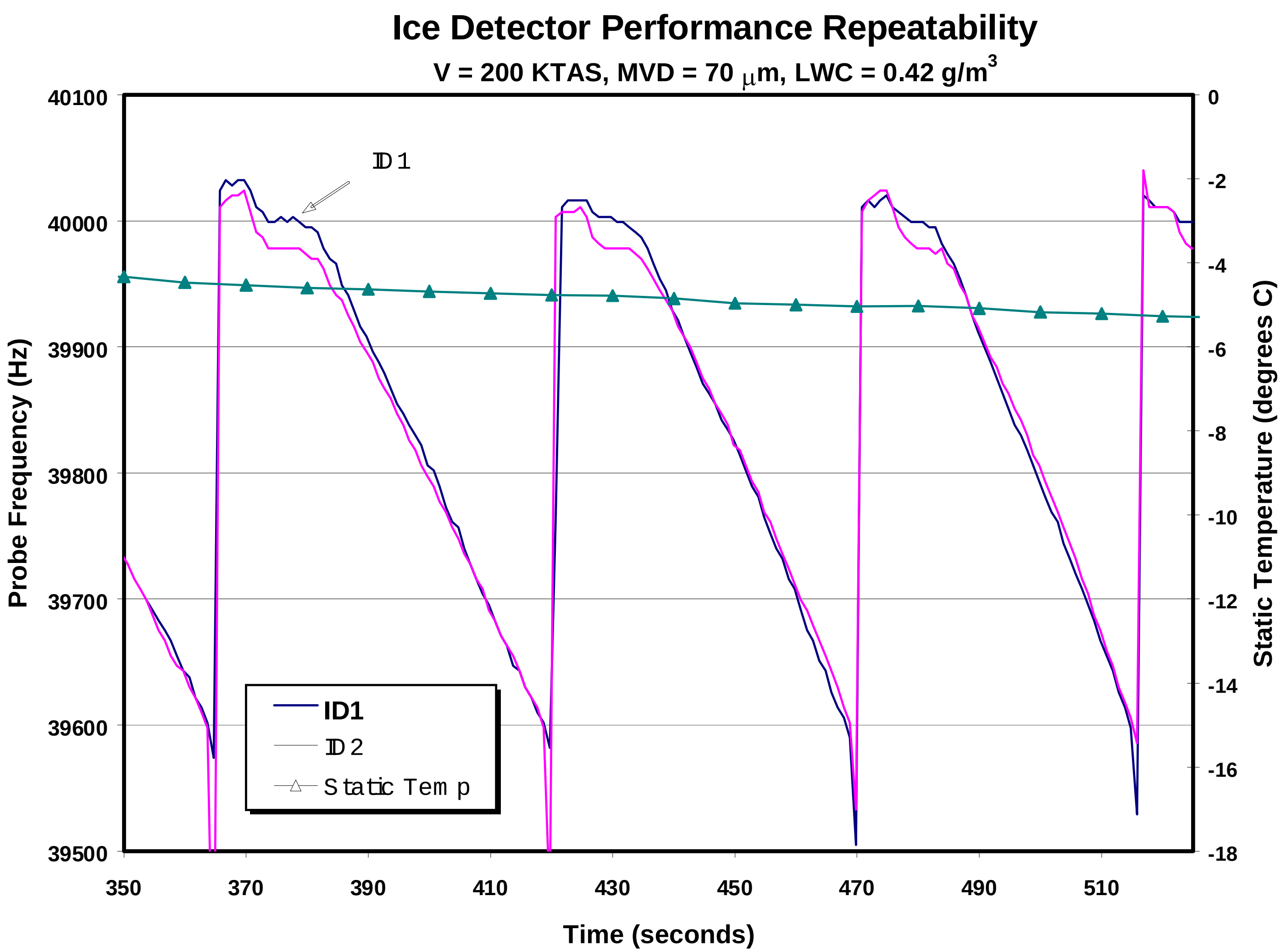
- Thus the amount of ice accreted on aircraft structures is a constant, regardless of the ice detection (response) time…

$$Ice\ \ Accreted\ \ On\ Wing = t \cdot W_{wing} \cong constant$$

Experimental Testing

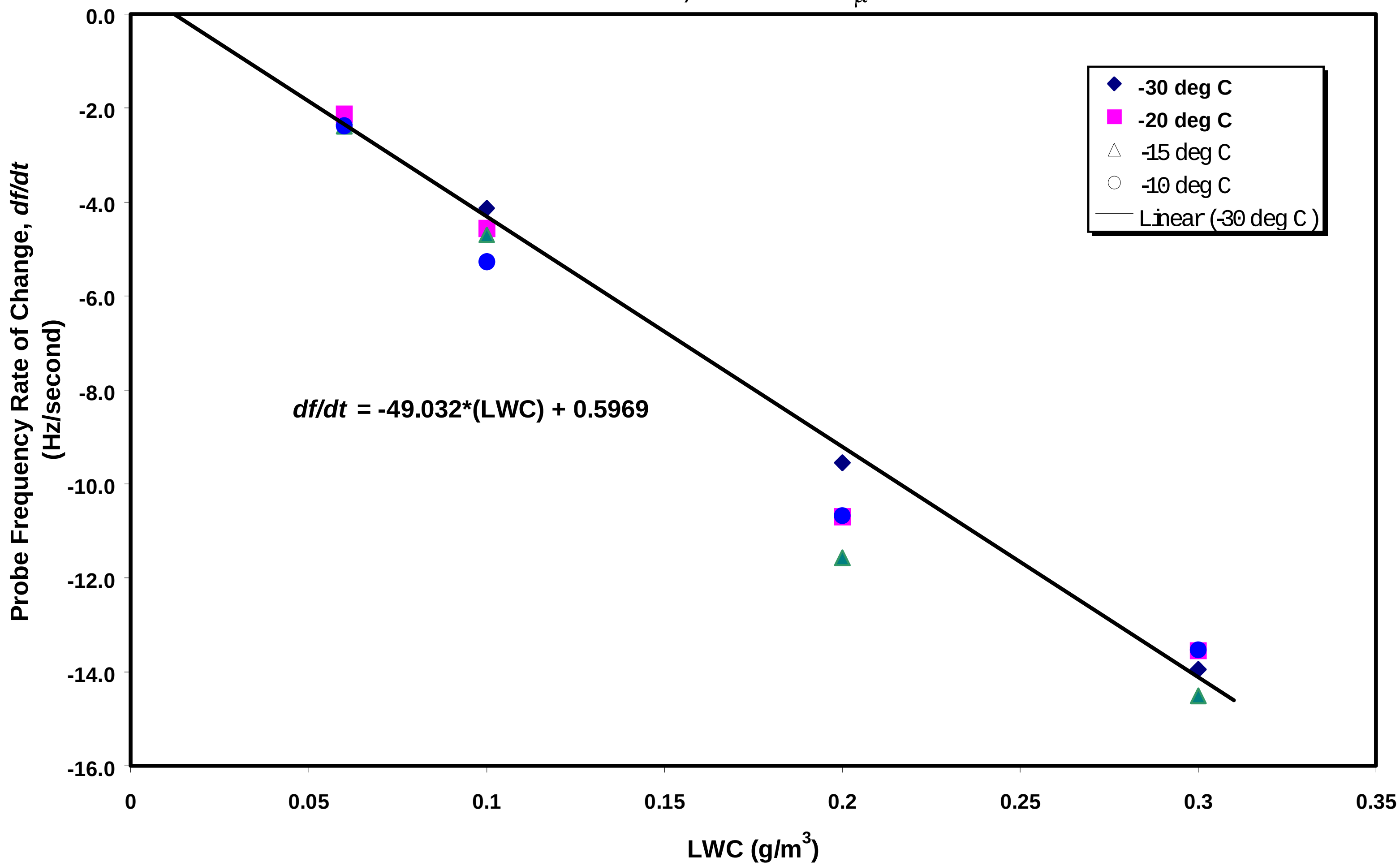
- Testing performed in the Goodrich Transonic Icing Tunnel and NASA Glenn IRT
  - Used modified Rosemount Aerospace 0871 Series ice detector with lower frequency trip point and frequency output via RS-232
- Testing focused on ice detector performance in low LWC and SLD conditions
  - Ice Detector Repeatability
    - cycle-to-cycle
    - unit-to-unit (tested 2 units with different nominal frequencies)
  - Low LWC threshold (sublimation vs detectability)
  - Does droplet splashing occur in SLD conditions such that the ice accretion rate is reduced?

Ice Detector Repeatability



Detectability at Low LWC

ID1 Frequency Rate of Change vs LWC
V = 195 KTAS, MVD = 20-30 μm



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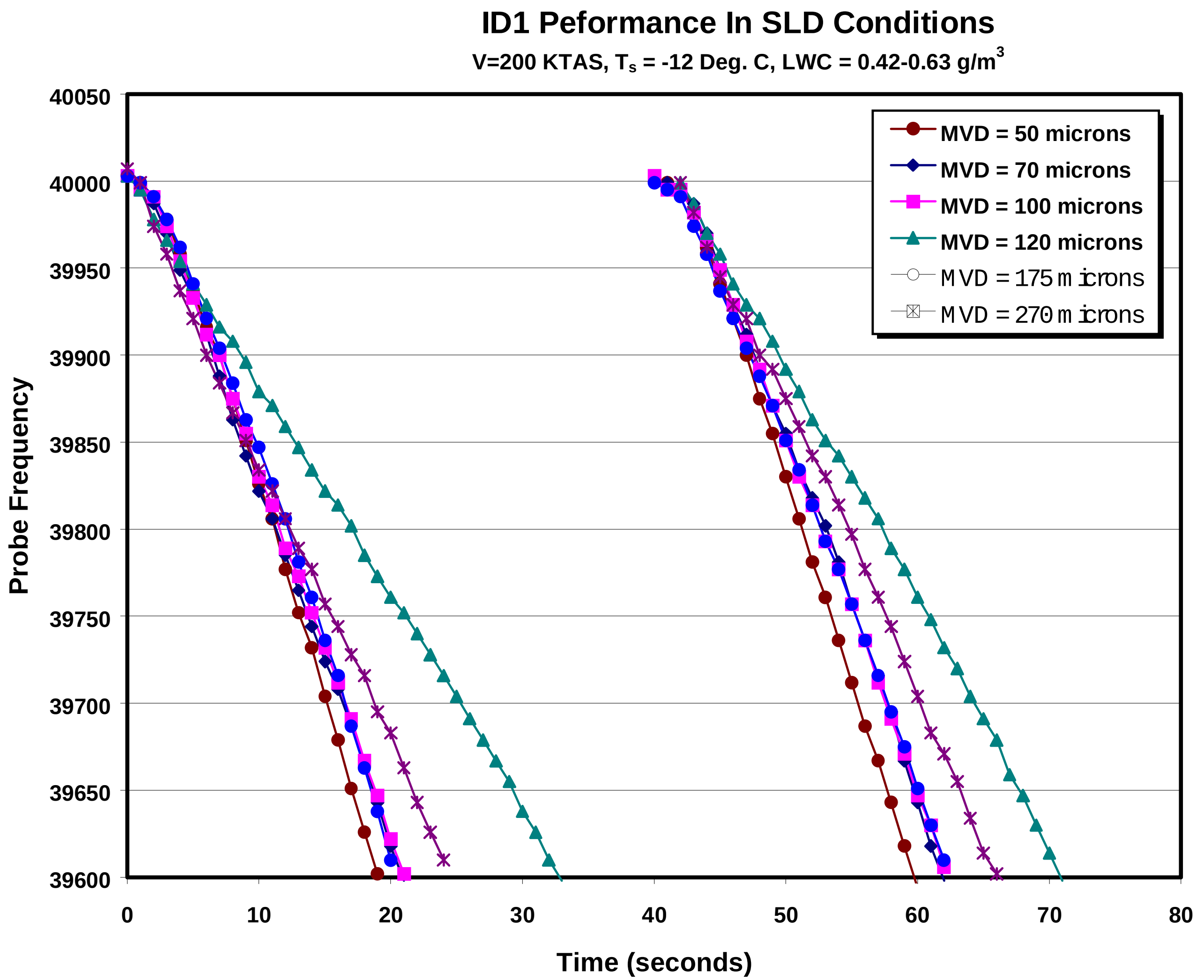
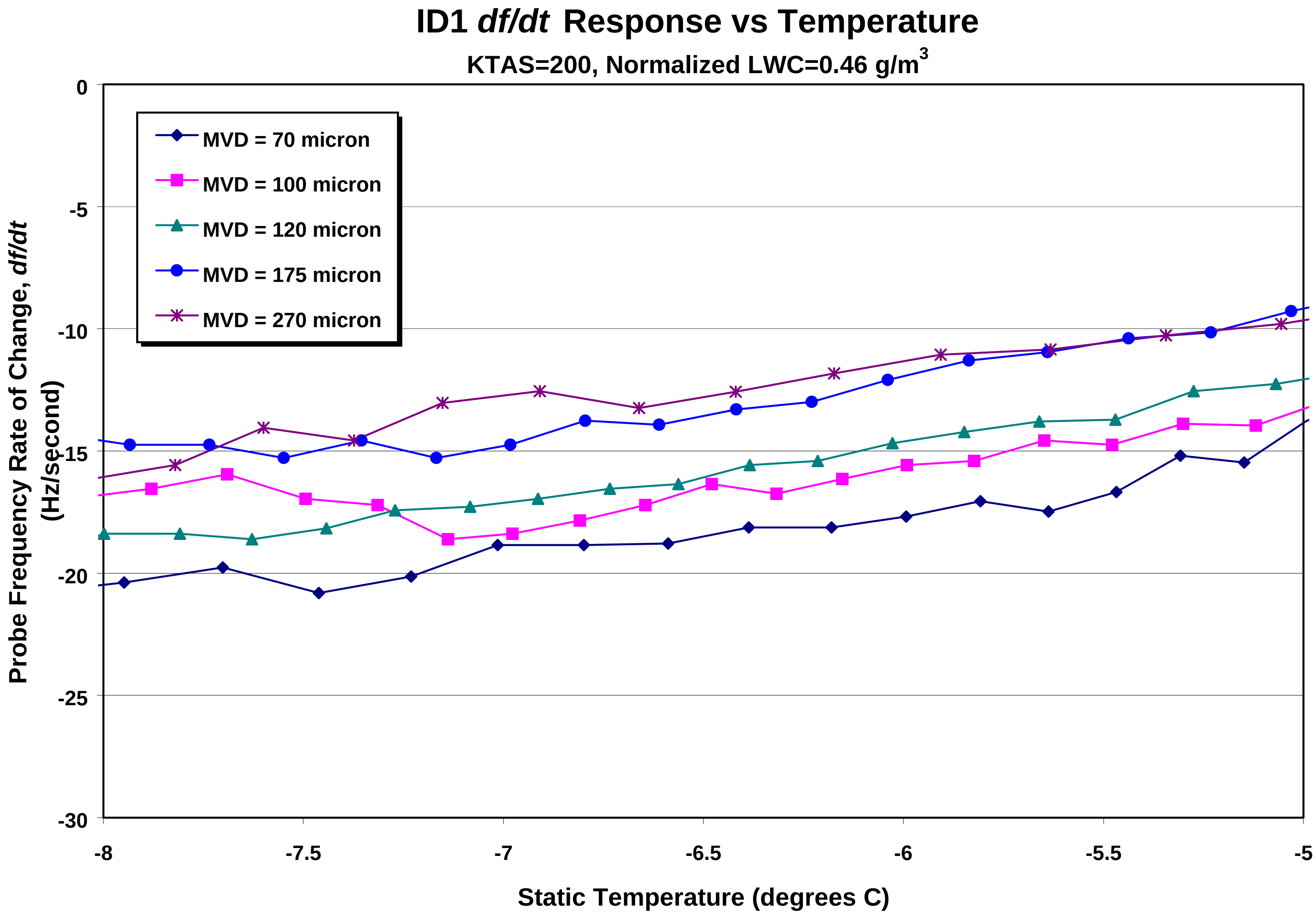
Detectability in SLD Conditions



Detectability in SLD Conditions



Summary / Conclusion

- Ice detector accretion (response) time is bounded by the minimum and maximum ice accretion rates.
- Ice detector cycle-to-cycle and unit-to-unit repeatability is very good.
- The ice detector can detect low LWCs; however, ice accretion at low LWCs may be reduced due to sublimation.
- Data suggests droplet splashing or perhaps thermal lag of large droplets in SLD conditions may cause a reduction in the ice accretion rate.
- The amount of ice accreted on aircraft structures is a constant, regardless of the ice detection (response) time.
- Sublimation, droplet splashing and other phenomena occur on all structures exposed to icing, and ice detector performance must be considered in that context.